PROJECT **facts**

Petroleum Exploration and Production

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U.S. DEPARTMENT OF ENERGY
OFFICE OF FOSSIL ENERGY
NATIONAL ENERGY TECHNOLOGY LABORATORY
STRATEGIC CENTER FOR NATIONAL GAS AND OIL

DE-FC26-00BC15307

CROSSWELL ELECTROMAGNETIC LOGGING TOOL

Improved logging between wells and through casing

PARTNERS

ElectroMagnetic Instruments, Inc.
Richmond, CA

Lawrence Livermore National Laboratory
Livermore, CA

Geo-BILT
Richmond, CA

ChevronTexaco
San Francisco, CA

Schlumberger
Houston, TX

MAIN SITES

EMI Test Site
Richmond, CA

Lost Hills Field
Kern County, CA

Kern River Field
Kern County, CA

Vacuum Field
Lea County, NM

Crosswell receiver prepared to lower in wellbore.

Background/Problem

Crosswell electromagnetic imaging technology, based on earlier radar imaging technology, will help interpret the reservoir rock and fluid flow through the reservoir between wells. The necessary resolution to accuratly map fluid properties has been missing from conventional seismic analyisis.

Crosswell electromagnetic imaging is designed to give accurate measurement of oil saturations in the areas between wells. Previous logging techniques could only generate oil saturation data close to the wellbore. Crosswell EM logging can provide the operator with an actual image of fluid migration and show where specific areas of undeveloped reservoir remain.

Project Description/Accomplishments

The Crosswell Electromagnetic Imaging Tool was developed at Lawrence Livermore National Laboratory (LLNL) between 1991 and 2000. ElectroMagnetic Instruments, Inc. (EMI) was created by former LLNL scientists to further the research and commercialization of the Crosswell Electromagnetic Imaging down-hole logging tool. EMI developed a five-well pattern test site in Richmond, CA to continue testing and construction of the tool prior to commercial field tests.

Crosswell electromagnetic logging involves the use of a string of receivers in one well and a transmitter lowered into a neighboring wellbore and moved up and down. The development of sensitive receivers, advanced transmitters and fiber optics was an essential part of the implementation of crosswell logging, and these advances from other sources have been incorporated into the development of the EM extended logging tool. The DOE project has refined transmitter design, geophone receiver design; and deployed the EM tool in uncased, fiberglass cased and steel cased wellbores.

EM logging depends on interpretation of 3-components; compressional, vertical shear and horizontal shear waves between transmitter and receiver. Use of a multiple array of receivers and moving the transmitter up and down the neighboring well allows imaging of a roughly elliptical region between the wells. Several transmitter-receiver combinations are used per survey to gather data. Currently EM logging of a 1,000 ft section of an uncased wellbore can be accomplished in 12 hours. The logging tool can be used in uncased and fiberglass cased wells with no difficultly, and has been successfully demonstrated when one well of a pair is steel cased. Steel casing significantly slows transmission time and interferes with the signals.

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CONTACT POINTS

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TOTAL ESTIMATED COST

$5 million

COST SHARING

LLNL Projects
DOE - $1.9 million

EMI Project
DOE - $0.8 million
Non- DOE - $0.4 million

WEBSITES

www.netl.doe.gov

Electromagnetic Instruments
www.emiinc.com

Field Demonstration Results

The first field applications of crosswell electromagnetic logging were: 1) a crosswell survey was conducted at Kern River oil field, CA in 1998 to map the residual oil saturation and determine the factors what controlled steam and oil flow in the heavy oil reservoir. Identification of the steam path allowed redesign of the steamflood to produce unswept areas. 2) Crosswell imaging applied at Lost Hills field, CA in 1997-98 imaged the waterflood performance of the Belridge diatomite. Chevron used two fiberglass cased wells to observe the results of water injection in this fractured reservoir. Imaging resistivity changes over time demonstrated that crosswell data could be used to map migration of the waterflood front providing an excellent means for understanding reservoir dynamics and optimizing the oil recovery process of the waterflood.

The Geo-BILT tool, a modified prototype electromagnetic imaging tool designed and tested by EMI, successfully demonstrated that multicomponent logging was applicable in several different geological environments. Geo-BILT has the advantage that it is capable of single well extended logging. The tool uses a transmitter situated 3 meters above the receivers on a line, and provides a 3-D image of the wellbore area up to a radius of 50 to 250 meters. Single well logging will significantly reduce logging cost, while providing critical reservoir data.

Crosswell electromagnetic imaging was used to monitor CO_2 injection performance in Vacuum field, NM operated by Chevron-Texaco. This 3-year DOE project involved development of crosswell EM dual steel casing logging tools, software development, data processing and imaging of low induction frequencies. The results were used to develop resistivity models showing the distribution, size and depth of the low resistivity zones which could be correlated to interwell CO_2 migration.

Benefits/Impacts

Crosswell Electromagnetic imaging has been successfully demonstrated for use in monitoring steamfloods, waterfloods and CO_2 floods. Crosswell EM imaging was proved to be 10 times more effective than the previous logging techniques used at Vacuum field to monitor CO_2 flooding. Information obtained from EM surveys will allow field operators to optimize production and produce more oil in a cost-effective manner. The progress of imaging through fiberglass and steel casing will significantly increase the application of the technique in regions where uncased wells can not be used. The newest advances in single wellbore imaging holds great potential for use in offshore drilling, where the expense of idling wells for logging procedures will be enhanced by reduction in the number of wells necessary to complete the EM survey.

Following successful demonstrations of the tool s effectiveness, specifically single borehole imaging, imaging through steel casing, and CO_2 monitoring, EMI was purchased by Schlumberger, a major oilfield service company. Schlumberger is backing the continued development and implementation of the Crosswell EM tool with a capital investment of $15 million, indicating their confidence that crosswell electromagnetic logging tools have a secure place in the future of the petroleum industry.